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The bill tip organ of the chicken (*Gallus gallus* var. *domesticus*)

MICHAEL J. GENTLE AND JOHN BREWARD

Agricultural and Food Research Council's Poultry Research Centre, Roslin, Midlothian EH25 9PS, Scotland

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INTRODUCTION

Complex arrangements of mechanoreceptors in the avian beak have been reported in a variety of species (Goglia, 1964; Bolze, 1969; Gottschaldt & Lausmann, 1974; Krulis, 1978; Berkhoudt, 1976, 1980). In the chicken, Gottschaldt & Lausmann (1974) reported the presence of 15–20 horny tubules in the lower beak but no similar structures were noted in the upper beak. Although Desserich, Fölsch & Ziswiler (1984) have made a systematic study of Herbst and Merkel corpuscles in the beak of the chicken before and after partial beak amputation, they make no specific mention of specialised beak tip structures. They report, however, that Merkel corpuscles can be found in particularly great numbers in the corium papillae of the beak tip.

These specialised dermal papillae with different kinds of receptors have features which are similar to many of the complex sensory structures found in mammals (Iggo & Gottschaldt, 1974).

In the goose it has been suggested that the presence of these dermal papillae may enable a higher resolution of tactile sensory information (Gottschaldt & Lausmann, 1974) and a similar argument has been put forward by Krulis (1978). In the mallard (Zweers & Wouterlood, 1973), woodcock & snipe (Goglia, 1964), and probably in many other species, food discrimination occurs at the level of the beak tip organ. The complex arrangements of mechanoreceptors in the beak of the Fringillidae are clearly correlated with the highly complex seed-husking mechanism of this group (Krulis, 1978).

There has, however, been no detailed account of the specialised dermal papillae found in the lower beak of the chicken. Since partial amputation of the beak (beak trimming) is a common agricultural practice, it is important to study these specialised sensory structures in detail so that the sensory deficits following their damage or removal can be fully evaluated.

MATERIALS AND METHODS

The surface features of the lower beak were studied using the scanning electron microscope. The lower beaks of three newly hatched chicks, which had been killed previously, were removed, mounted and gold sputter coated using a Polaron E 5100 Sputter Coater. The surface features of the beak were then examined using a Cambridge Stereoscan 180.

To investigate the general structure of the beak tip histologically, 5 weeks old birds were used. Fifteen birds were killed, the lower beak was removed and fixed for

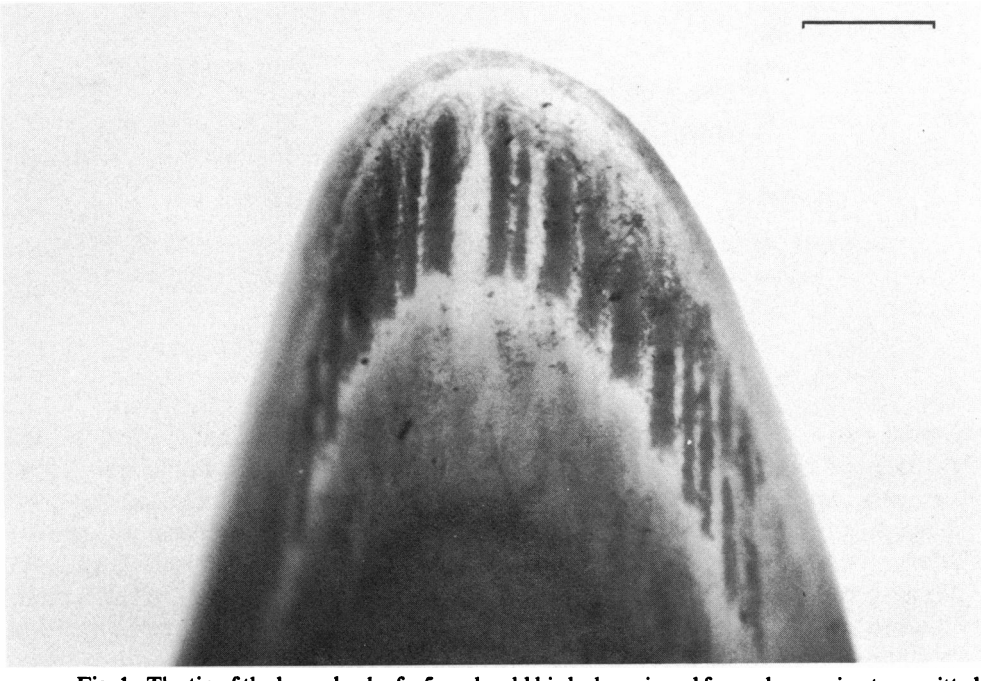

Fig. 1. The tip of the lower beak of a 5 weeks old bird when viewed from above using transmitted light. The dermal papillae can be clearly seen. Calibration bar, 0·5 mm.

2 weeks in 10% formol saline. Following fixation, they were decalcified in a 10% formic acid formalin solution for 2 weeks and washed in running water overnight. The outer keratin of the beak proved to be very difficult to section and in some beaks it was removed mechanically with a scalpel before further processing. In other beaks, the keratin was softened with a solution of 4% calcium thioglycolate in water for 2 weeks. Following washing the beaks were dehydrated in three changes of dioxan, vacuum embedded in Fibrowax (P. A. Lamb) and serially sectioned (longitudinally) at a thickness of 10 μm. The sections were stained with either haematoxylin and eosin, Bodian's protargol or Masson's trichrome.

RESULTS

The presence of 15–20 dermal papillae in the tip of the lower beak which had been reported by Gottschaldt & Lausmann (1974) was confirmed. These could be seen clearly when the lower beak was viewed from above using transmitted light (Fig. 1). No comparable structures were seen in the upper beak.

The surface features of the inside of the lower beak are shown in Figure 2. There is a single row of oval, shallow pits situated just inside the mouth caudal to the cutting edge (tomial edge) of the beak. These surface pits corresponded to the ends of the dermal papillae. There was no suggestion of any specialised tactile structures in or adjacent to these pits.

Low magnification photomicrographs of sections taken at the end of the lower beak with the keratin intact (Fig. 3) showed the finger-like dermal and epidermal projections into the thick keratin (the rhamphotheca) of the exterior of the beak. The epidermal cells in these papillae extended to the periphery and, although the

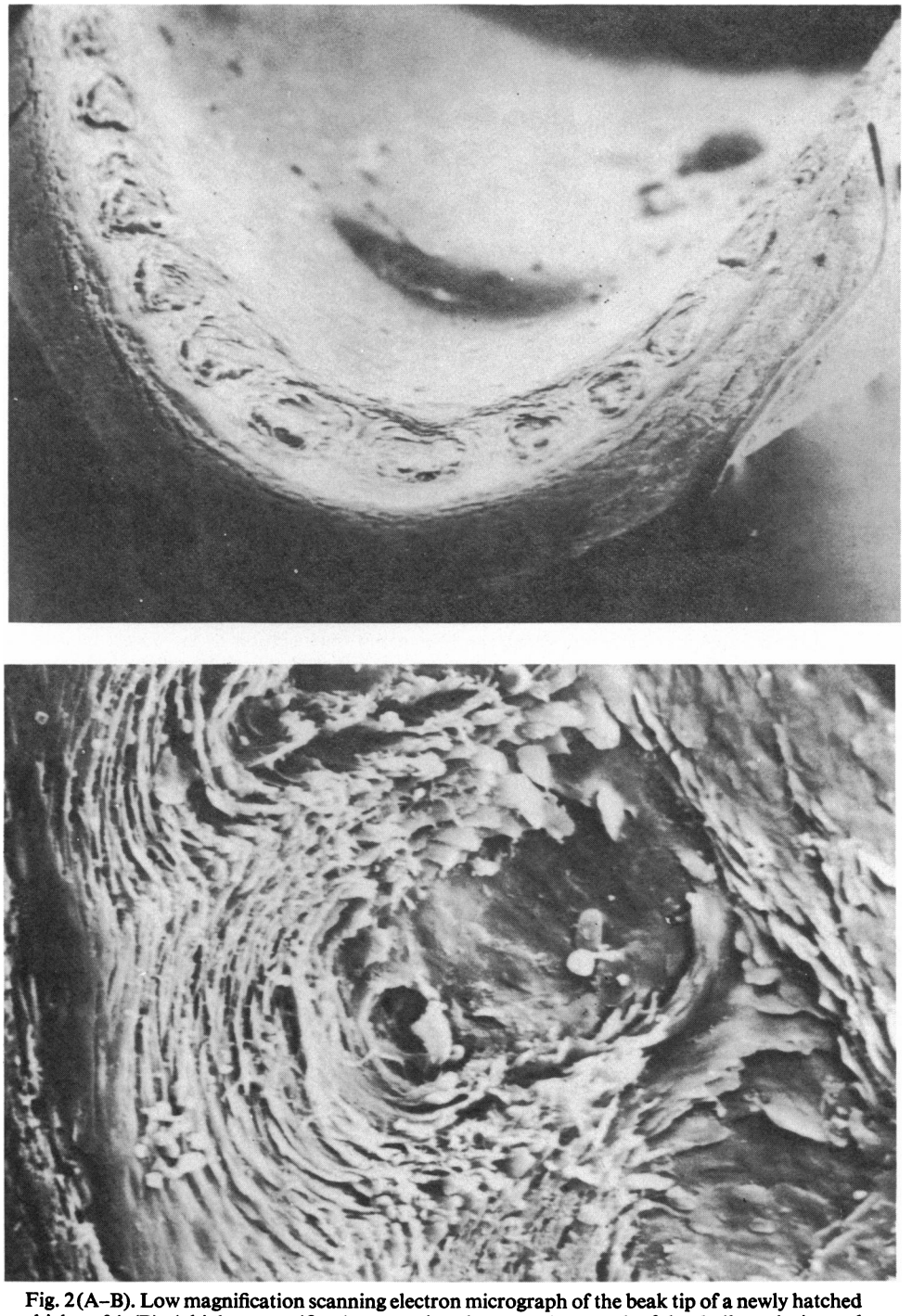

Fig. 2(A–B). Low magnification scanning electron micrograph of the beak tip of a newly hatched chick. × 34. (B). A higher magnification scanning electron micrograph of the shallow pit situated on the beak just inside the mouth. × 396.

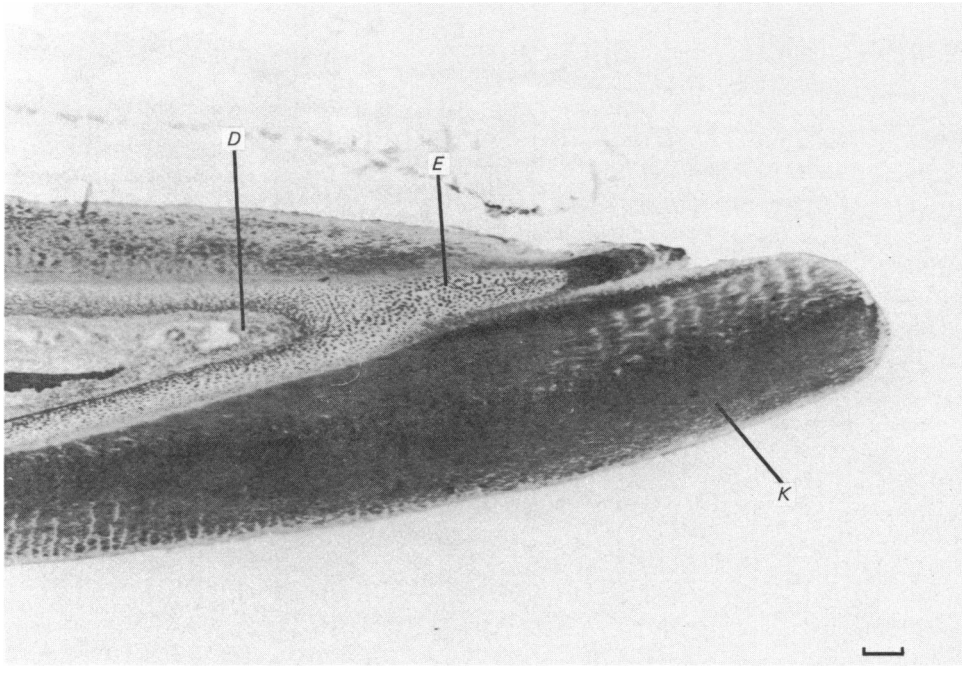

Fig. 3. Low magnification photomicrograph of a 10 μm thick section of the tip of the beak stained with Bodian's protargol showing the finger-like dermal (*D*) and epidermal (*E*) projection through the thick outer keratin (*K*) of the beak. Calibration bar, 100 μm.

nuclei became flattened, the degree of keratinisation was less extensive than that seen in the surrounding rhamphotheca. The dermis extended some distance into the papillae and contained numerous blood vessels and nerve fibres. At the base of the papillae, there was a cluster of Herbst corpuscles. Usually three Herbst corpuscles were present in each papillae (Fig. 4) but in some papillae five corpuscles have been seen. Because of the closeness of the papillae and the large size of the Herbst corpuscles, estimates for their number per papilla were difficult to obtain. In the distal parts of the papillae, there were large numbers of corpuscles of the Merkel (Grandry) type. These were orientated within the papillae at right angles to their normal orientation within the dermis. In the dermis, Merkel corpuscles were often found directly below the epidermis with the longitudinal axis of the individual tactile cells aligned parallel to the surface of the epithelium.

DISCUSSION

The dermal papillae of the beak tip of the chicken show many structural similarities to the bill tip organ of the duck (Berkhoudt, 1976; 1980) and the goose (Gottschaldt & Lausmann, 1974): there are large numbers of Merkel (Grandry) corpuscles in the distal region of the papillae and Herbst corpuscles in the proximal region. The Merkel corpuscles of the chicken and quail have numerous similarities with the Grandry corpuscles of chicks and geese (Anderson & Nafstad, 1968; Nafstad, 1971; Saxod 1978). Ide & Munger (1978), on the basis of morphological, physiological and embryological evidence, have proposed the term 'Grandry corpuscles' for all avian dermal sensory corpuscles containing the characteristic Grandry cells. Confusion in

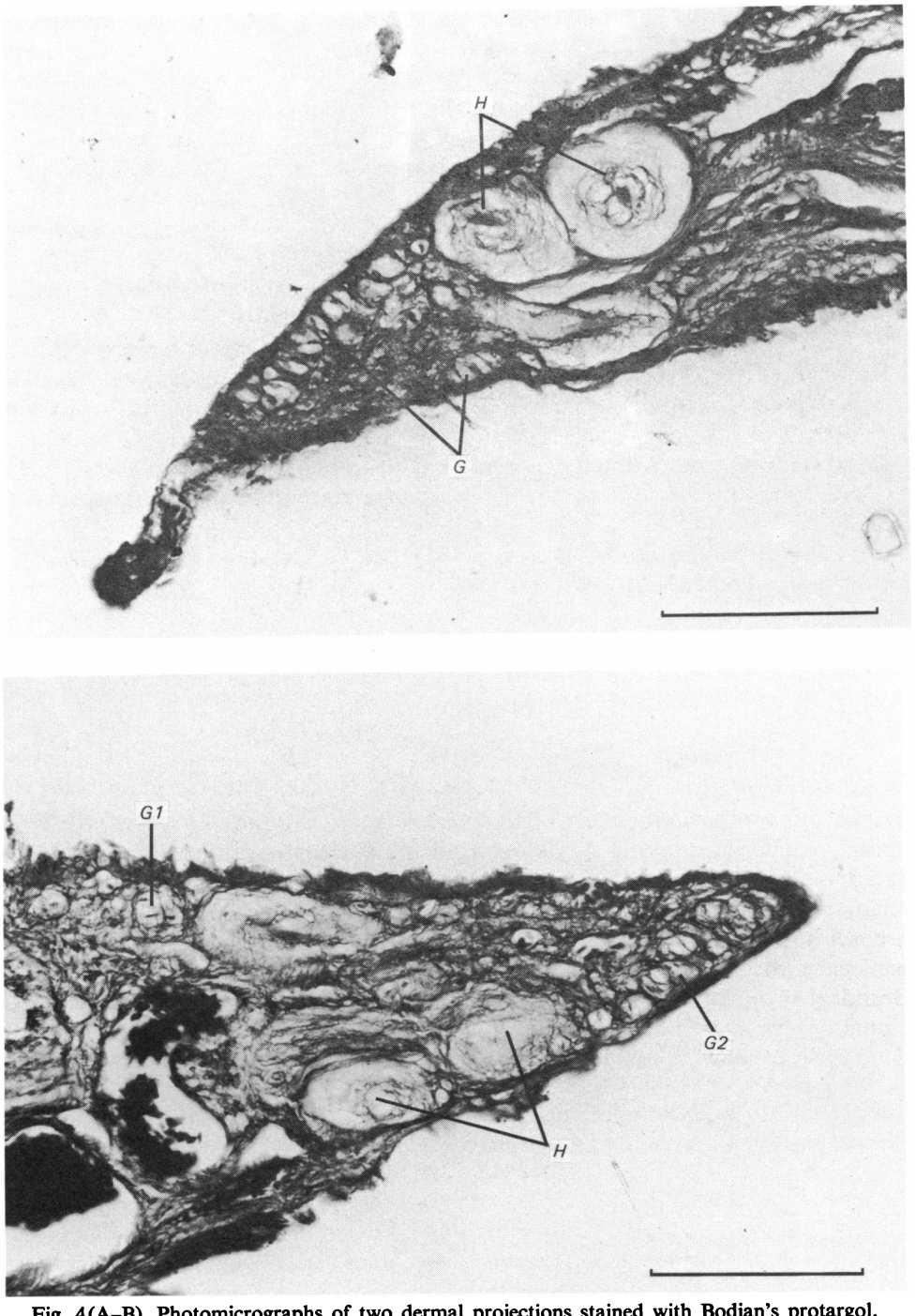

Fig. 4(A–B). Photomicrographs of two dermal projections stained with Bodian's protargol. (A) This shows Herbst (*H*) and Grandry (*G*) corpuscles. (B) The difference in orientation of the Grandry corpuscles can be seen with those at the base of the papillae (*G1*) showing their normal epithelial orientation, i.e. longitudinal axes parallel to the surface, whereas those in the papillae (*G2*) are at right angles to it. Calibration bar, 100 μm.

terminology, however, still arises and Desserich *et al.* (1984), working on the chicken, have recently reported the presence of Merkel corpuscles but state that they cannot find any Grandry corpuscles.

Both the Herbst and the Grandry corpuscles are considered to be very sensitive, rapidly adapting mechanoreceptors (Dorward, 1970; Gottschaldt, 1974; Gregory 1973; Leitner & Roumy, 1974; Leitner, Roumy & Saxod, 1973). The free nerve endings observed by Desserich *et al.* (1984) are likely to respond to thermal stimulation and noxious stimulation (Breward, 1984) and to give responses to prolonged maintained displacement. Perhaps the reduced keratinisation of the cells in the tip of the papillae permits a greater displacement of the softer tissue than the surrounding rhamphotheca and would allow for an increased sensitivity. The large number of mechanoreceptors in the papillae suggests that, as with many other birds, the chicken has developed these specialised structures in the tip of the beak to provide the necessary fine tactile discrimination to enable them to perform a number of complex oral tasks. The absence of these specialised dermal papillae in the upper beak are of considerable interest. Although dermal papillae, Merkel (Grandry) and Herbst corpuscles are all present in the upper beak, they are not arranged into specialised papillae.

The papillae being so close to the most distal point of the beak, partial amputation, however, slight, must lead to a considerable loss of sensory input which may be reflected in the feeding difficulties shown by the birds after this procedure (Gentle, Hughes & Hubrecht, 1982). Breward & Gentle (1985) have provided evidence for both acute and chronic pain followed beak trimming, though it is not certain how these relate to loss of the specialised sensory organs.

SUMMARY

At the tip of the lower beak of the chicken there were found 15–20 specialised dermal papillae containing large numbers of mechanoreceptors. The Merkel or Grandry corpuscles were situated distally in the papillae and at the papillae base was a collection of Herbst corpuscles. The apex of the papillae, under the scanning electron microscope, appeared as a row of shallow pits on the surface of the beak just inside the mouth. These papillae resemble similar structures seen in other birds and are probably necessary for fine tactile discrimination.

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